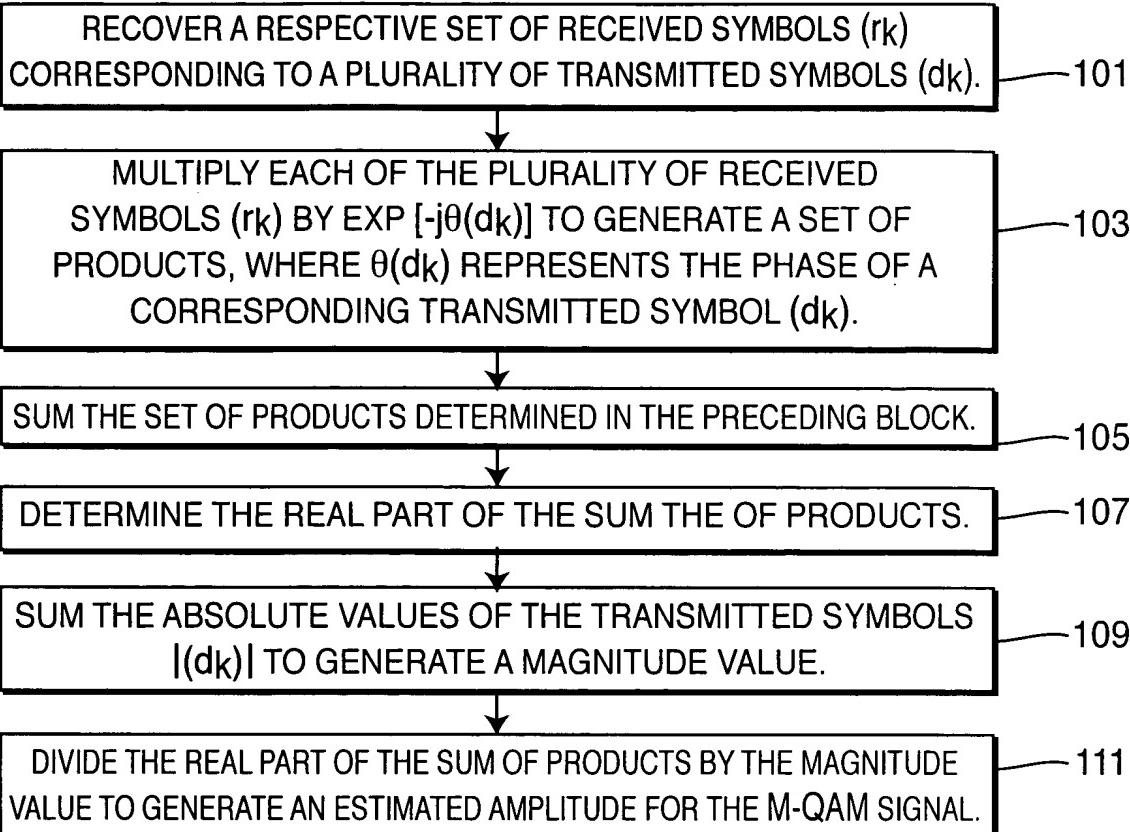
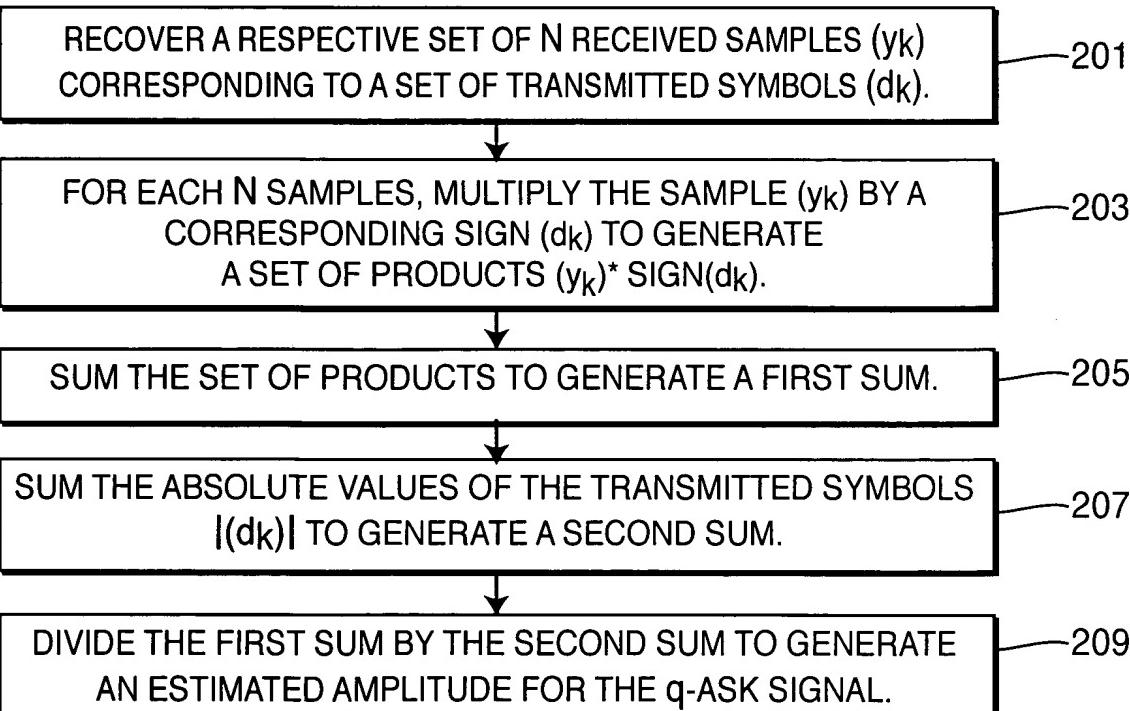
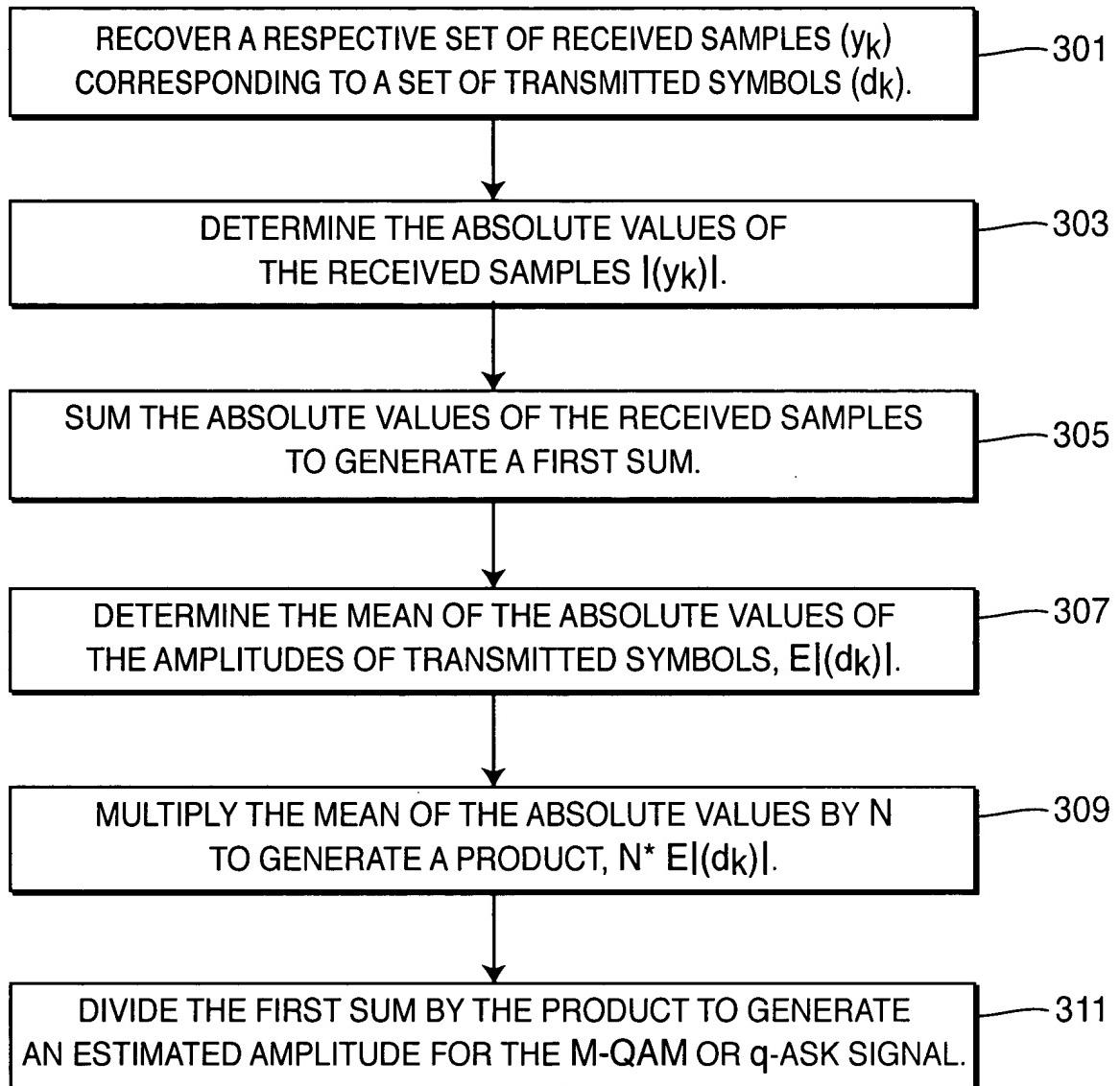


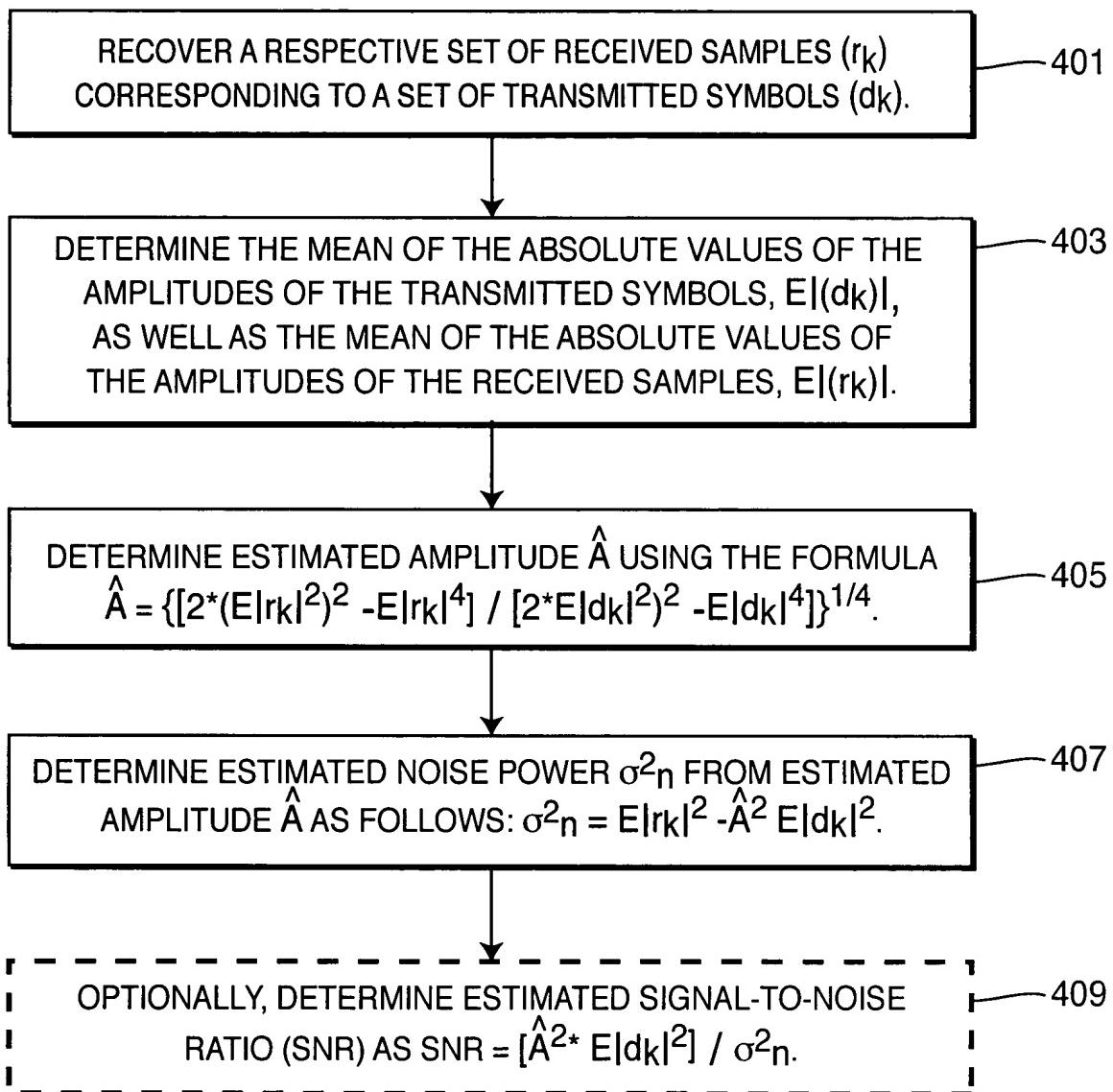
100

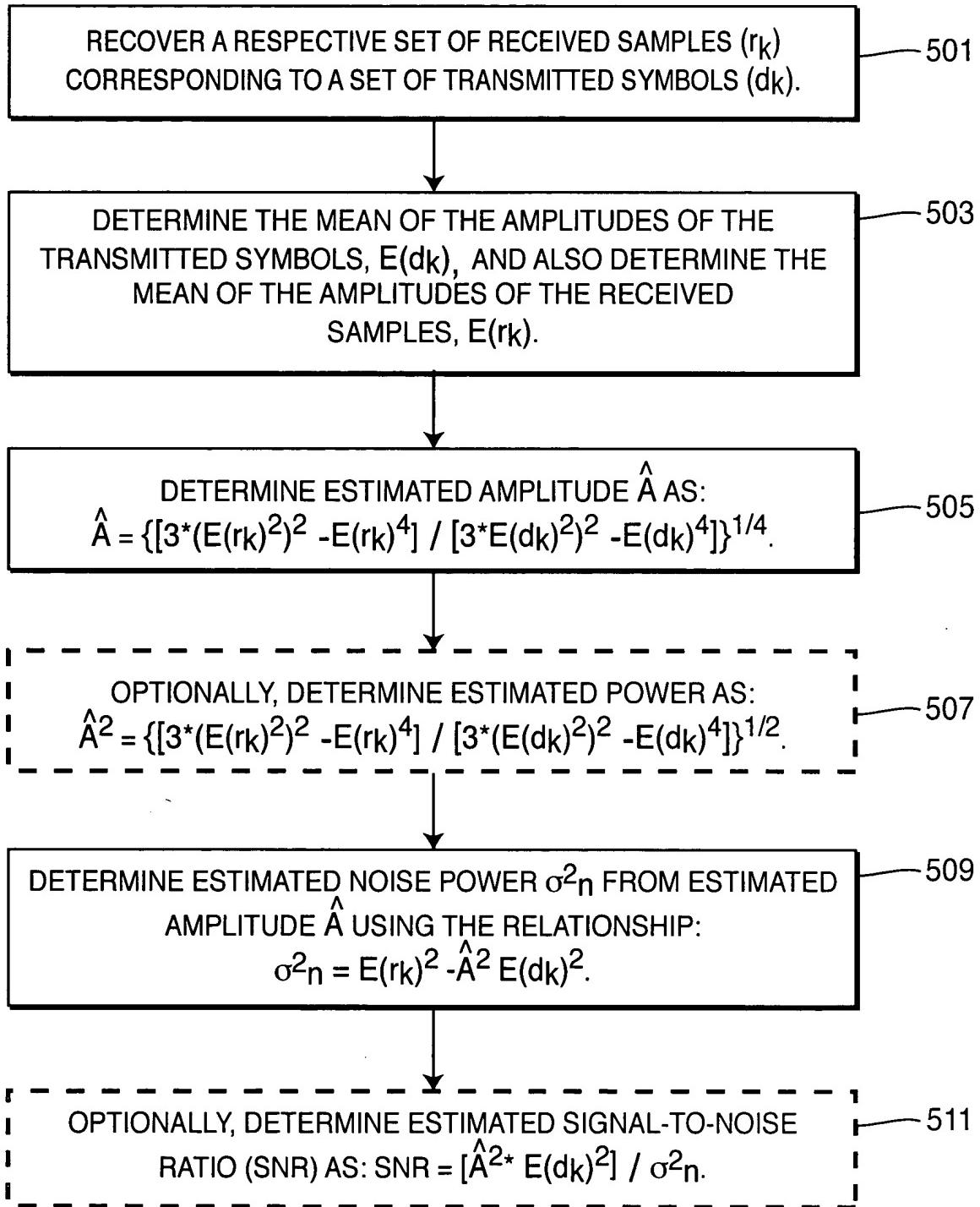
**FIG. 1**

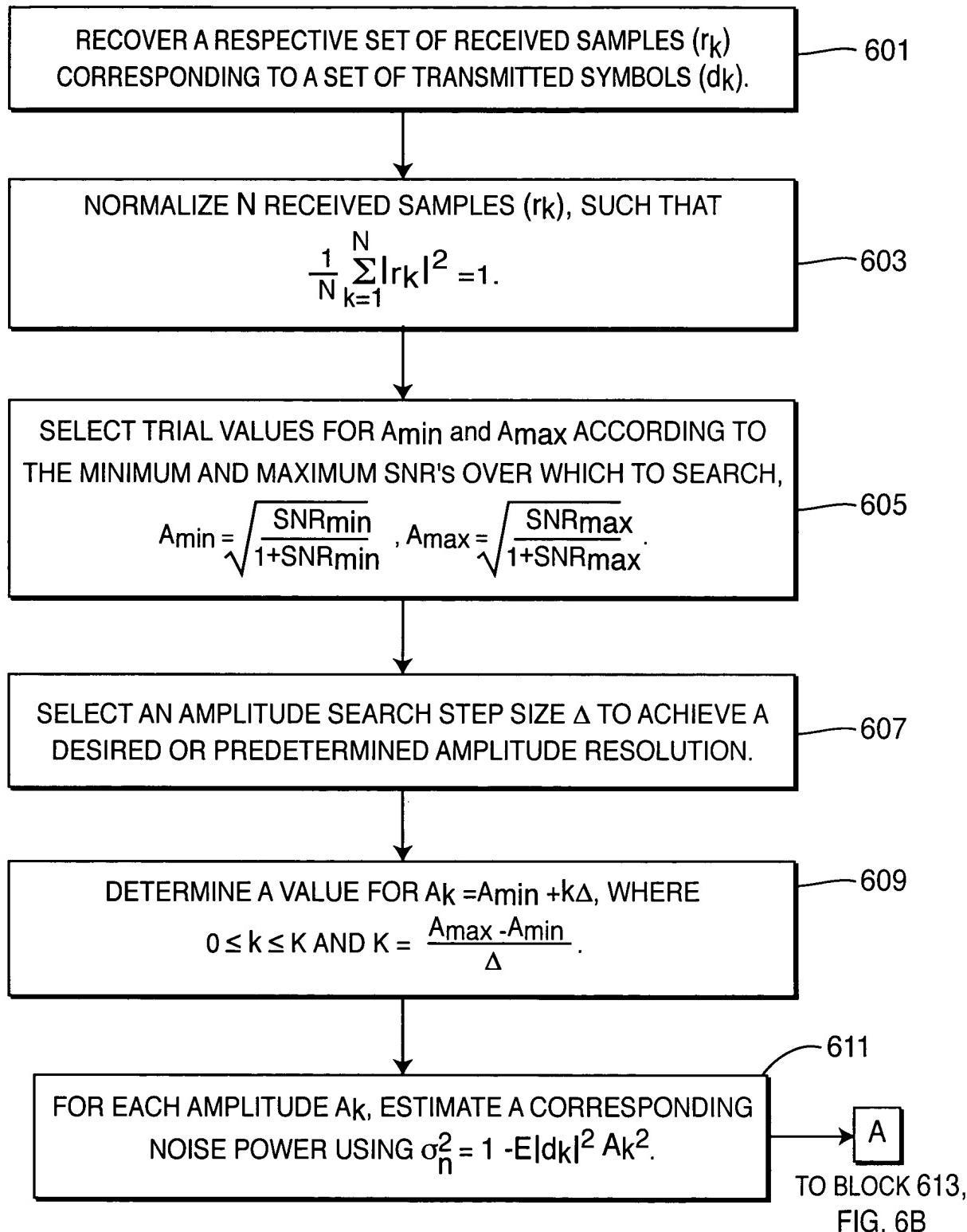
200

**FIG. 2**

**FIG. 3**

**FIG. 4**

500**FIG. 5**

**FIG. 6A**

600

6/8

A →
FROM BLOCK
611,
FIG. 6A

DETERMINE A JOINT PROBABILITY DENSITY FUNCTION
 $f(A_k, \sigma_n; r_1, r_2, \dots, r_N)$ FOR EACH A_k , WHERE A
 PROBABILITY DENSITY FUNCTION OF r_k IS DEFINED AS

$$f(A, \sigma_n; r_k) = \frac{1}{\sqrt{2\pi}\sigma_n} \sum_{m=1}^M \exp\left(-\frac{|r_k - A_m|^2}{2\sigma_n^2}\right)$$

FOR AN M-QAM SIGNAL. IN THE CASE OF A q-ASK SIGNAL,
 THE PROBABILITY DENSITY FUNCTION IS DEFINED AS

$$f(A, \sigma_n; r_k) = \frac{1}{\sqrt{2\pi}\sigma_n} \sum_{m=1}^M \exp\left(-\frac{(r_k - A_m)^2}{2\sigma_n^2}\right), \text{ WHERE}$$

$$a_m = (-1)^m \left(\left\lfloor \frac{m-1}{2} \right\rfloor + \frac{1}{2} \right). \text{ ASSUMING THE RECEIVED}$$

SAMPLES ARE INDEPENDENT, THE JOINT PROBABILITY
 DENSITY FUNCTION OF r_1, r_2, \dots, r_N

$$\text{IS } f(A, \sigma_n; r_1, r_2, \dots, r_N) = \prod_{k=1}^N f(A, \sigma_n; r_k).$$

613

FIND A VALUE FOR THE ESTIMATED AMPLITUDE,
A, THAT MAXIMIZES THE JOINT PROBABILITY
 DENSITY FUNCTION AS FOLLOWS:
 $\hat{A} = \arg \max f(A, \sigma_n; r_1, r_2, \dots, r_N).$

615

SEARCH TO FIND A VALUE FOR A_k THAT
 CORRESPONDS TO THE MAXIMUM JOINT
 PROBABILITY DENSITY FUNCTION.

617

B

TO BLOCK 619,
 FIG. 6C

FIG. 6B

600

7/8

B →
FROM BLOCK 617,
FIG. 6B

SUBSTITUTE THE VALUE FOR A_k DETERMINED
IN THE PRECEDING STEP INTO EQUATION
 $\hat{A} = \arg \max f(A_k, \sigma_n; r_1, r_2, \dots, r_N)$ TO OBTAIN
A VALUE FOR \hat{A} , REPRESENTING AN ESTIMATED
AMPLITUDE VALUE.

619

OPTIONALLY, DETERMINE A VALUE FOR
ESTIMATED NOISE POWER FROM ESTIMATED
AMPLITUDE \hat{A} AS FOLLOWS:
 $\sigma_n^2 = E(r_k)^2 - \hat{A}^2 E(d_k)^2$.

621

OPTIONALLY, DETERMINE A VALUE FOR
ESTIMATED SIGNAL-TO-NOISE (SNR) FROM
THE RELATIONSHIP SNR =
 $[\hat{A}^2 * E(d_k)^2] / \sigma_n^2$.

623

FIG. 6C

700

A →
FROM FIG. 7A,
BLOCK 707

ESTIMATE SIGNAL-TO-NOISE (SNR) USING:

$$\text{SNR} = \frac{(2 - \text{Kurt}(r)) + \sqrt{(4 - 2K_{M-QAM}) - (2 - K_{M-QAM})\text{Kurt}(r)}}{(\text{Kurt}(r) - K_{M-QAM})}$$

709

FIG. 7B

DETERMINE SECOND-ORDER AND FOURTH-ORDER MOMENTS OF A SET OF RECEIVED SAMPLES (r_k). THE SECOND-ORDER MOMENT IS DEFINED AS $E\{|r_k|^2\} = E\{|n_k|^2\} + E\{|d_k|^2\}$, AND THE FOURTH-ORDER MOMENT IS DEFINED AS $E\{|r_k|^4\} = E\{|n_k|^4\} + E\{|d_k|^4\} + E\{|n_k|^2\}E\{|d_k|^2\}$, WHERE d_k DENOTES THE TRANSMITTED SYMBOLS AND n_k DENOTES A NOISE COMPONENT THAT IS RECOVERED WITH THE RECEIVED SAMPLES r_k .

DIVIDE THE FOURTH-ORDER MOMENT BY THE SECOND-ORDER MOMENT SO AS TO IMPLEMENT A KURTOSIS OPERATION AS FOLLOWS:

$$\text{Kurt}(r) \equiv \frac{E\{|r_k|^4\}}{E\{|r_k|^2\}^2} = \frac{E\{|d_k|^4\} + E\{|n_k|^4\} + 4E\{|d_k|^2\}E\{|n_k|^2\}}{E\{|d_k|^2\}^2 + E\{|n_k|^2\}^2 + 2E\{|d_k|^2\}E\{|n_k|^2\}}$$

THE FOREGOING EXPRESSION FOR KURTOSIS INCLUDES A FIRST KURTOSIS COMPONENT ATTRIBUTABLE TO THE RECEIVED SIGNAL, AND A SECOND KURTOSIS COMPONENT CORRESPONDING TO THE RECEIVED NOISE.

DETERMINE THE SECOND COMPONENT OF KURTOSIS, CORRESPONDING TO RECEIVED NOISE, AS FOLLOWS: ASSUMING THE EXISTENCE OF COMPLEX CIRCULARLY SYMMETRIC GAUSSIAN NOISE, THE KURTOSIS OF THE NOISE COMPONENT ALONE IS

$$K_{CG} \equiv \frac{E\{|n_k|^4\}}{E\{|n_k|^2\}^2} = 2.$$

DETERMINE THE FIRST COMPONENT OF KURTOSIS, CORRESPONDING TO THE SIGNAL, (K_{sig}), AS

$$K_{sig} \equiv \frac{E\{|d_k|^4\}}{E\{|d_k|^2\}^2}. \text{ IN THE CASE OF AN M-QAM SIGNAL, } K_{sig} \text{ IS}$$

DENOTED AS $K_M\text{-QAM}$.



TO FIG. 7B,
BLOCK 709

FIG. 7A